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Development of an Algorithm for the EMG Control of Prosthetic Hand

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Abstract. This work presents the development of a new algorithm for the control of robotic and prosthetic hands: the proposed architecture is made of an EMG wearable sensor and a personalized Graphical User Interface (GUI).

The proposed system inherits and processes eight EMG signals which are locally amplified and rectified within the wearable device: then a signal classifier allows piloting a 2 degree of freedom cursor on the GUI in order to reach a provided target in the Cartesian space.

The aim of this study is to finally provide a user-friendly interface for training human subjects on reaching movements with the EMG signals of their forearm muscles. This approach as a twofold objectives: (1) to maintain, train and support the muscular tone and (2) to provide an interface for the physiotherapy and preparation of prosthetic use in daily life.

Keywords: intelligent systems, EMG, smart devices, human-device interaction.

1 Introduction

There are more than 1 million annual limb amputations globally, one every 30 s [1]. Such amputations are touching daily life of these people since amputee are often affected by huge incapacity to perform basic tasks at their home, work and in their social environment.

At the same time, recent scientific developments are providing novel tools in order to help and support such casualties, particularly with the increasing diffusion of robotics and prosthetics [2-4]. An important role on this field is also performed by science in general and the growing of Artificial Intelligence (AI) which makes some of device in the market smarter and more efficient in terms of higher motion capability, higher bio-mimetics, better signal interpretation and so on [5,6].

Here we are proposing an integrated system where physiological signals can be used to pilot a user-friendly graphical interface in order to enhance the muscular tone of upper limbs while providing a potential tool for the control of prosthetic devices in a 'natural' way [7]. The paper is organized into two sections: in the first part - Materials and Methods -, we characterize the main components of the system and in the second part - The EMG Graphical User Interface - we focus on the algorithm and outcome of the proposed architecture.

2 Materials & Methods

In this section the overall system is presented with its own hardware and software components.

2.1 The Processing Environment

Processing is an open-source graphical library and Integrated Development Environment (IDE) or playground “built for the electronic arts, new media art, and visual design communities with the purpose of teaching non-programmers the fundamentals of computer programming in a visual context” [8]. Processing is based on the Java Programming Language, with the possibility of adding classes and mathematical functions. It allows the development of Graphical User Interface (GUI) and the interaction with input and output of different nature (Figure 1)

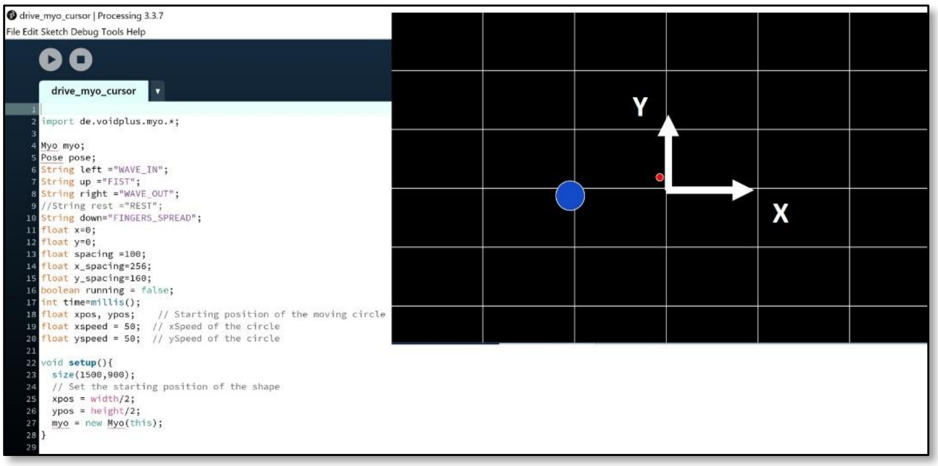


Figure 1 – An overview of the proposed algorithm in Processing Programming Language (left panel) and its resulting graphical outcome (right panel)

2.2 The Myo Bracelet

The Myo Bracelet is a werable and commercial device for the acquisition, processing and wireless communication of EMG signals, namely the ElectroMyoGraphic output coming from the muscle contraction [9]. The device is made of two main components: the bracelet itself and a USB dongle to be used combined with a

Computer in order to collect the bracelet information. The device is also provided with a software and a set of libraries or SDK for the design of solutions and prototype (Figure 2).

Figure 2 – The Myo bracelet (1), a pictorial representation of its functioning (2) and the default user interface software mask (3) (source: RobotShop and Thalamic Lab)

3 The EMG Graphical User Interface

An EMG GUI has been developed: the interface collect the classified EMG signals from the wearable bracelet and allows the navigation of a mobile cursor on a grid which is projected on the screen. Namely, the moving cursor is activated and driven by the Myo signals, whereas a static cursor, i.e. the target, is provided through the input of *x*, *y* Cartesians coordinates. This navigation cursor aims at reaching a random target on the grid (Figure 3).

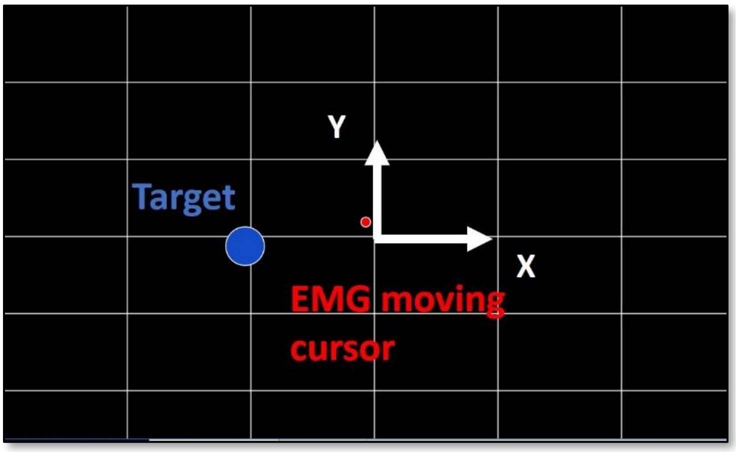


Figure 3 – Overview of the EMG Graphical User Interface with the target or static marker and the EMG cursor or mobile marker, in blue and red color, respectively

As soon as the target is reached, then the navigation cursor is returned to the home position (namely the position of coordinates $x = 0$ and $y = 0$) and a novel target is provided. The interface is managed through the following structured sequence of events which are implemented in the controlling algorithm under the Processing programming Language:

- Step 1 - Target positions (x_{tg}, y_{tg}) are acquired from a list of target provided via an Excel file
- Step 2 - EMG signals are real-time detect from the forearm muscles' contraction
- Step 3 - An embedded classification of the EMG signals is performed in order to identify 4 different hand configurations, namely (Figure 4):
  - *Wave in*
  - *Wave out*
  - *Fist*
  - *Open Hand*

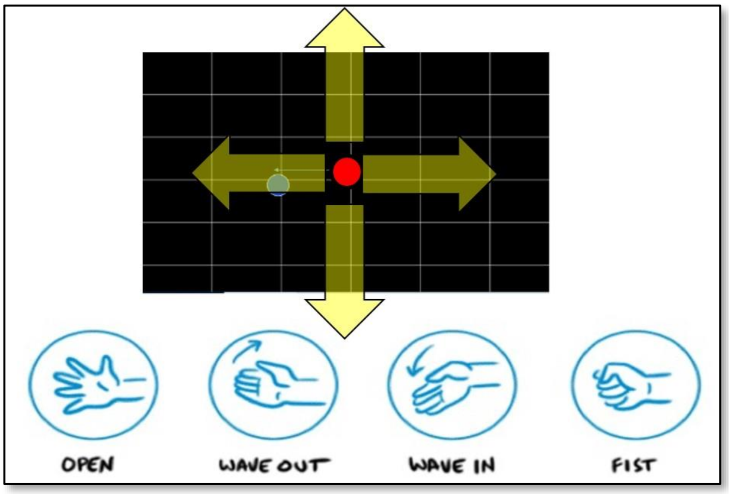


Figure 4 – Overview of the EMG classification (as internally performed within the Myo/Thalamic Software) and of the 4 direction of the EMG mobile cursor

- Step 4 - A conversion of the assigned class is performed into 4 different possible movements of the mobile cursor within the projected grid, according to the following mapping (Figure 5):

    - *Wave in* maps into a cursor movement to the *left* of the grid
    - *Wave out* maps into a cursor movement to the *right* of the grid
    - *Fist* maps into a cursor movement to the *top* of the grid
    - *Open Hand* maps into a cursor movement to the *bottom* of the grid

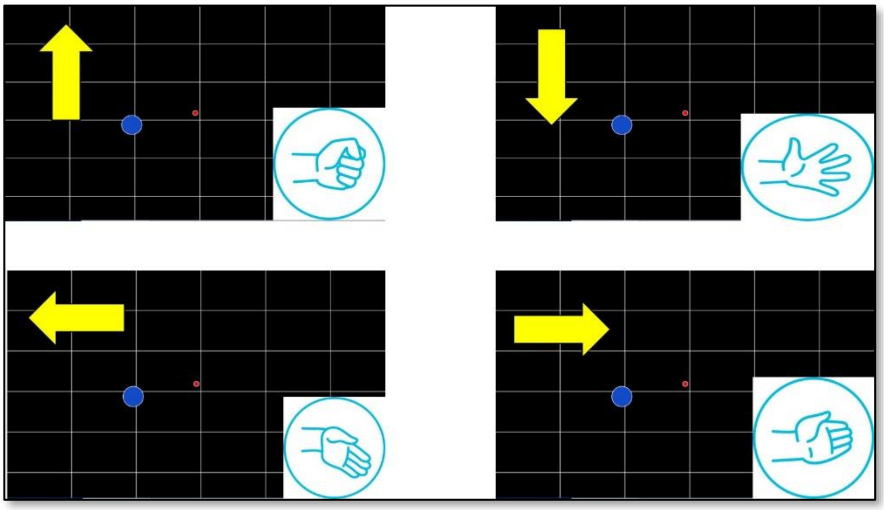
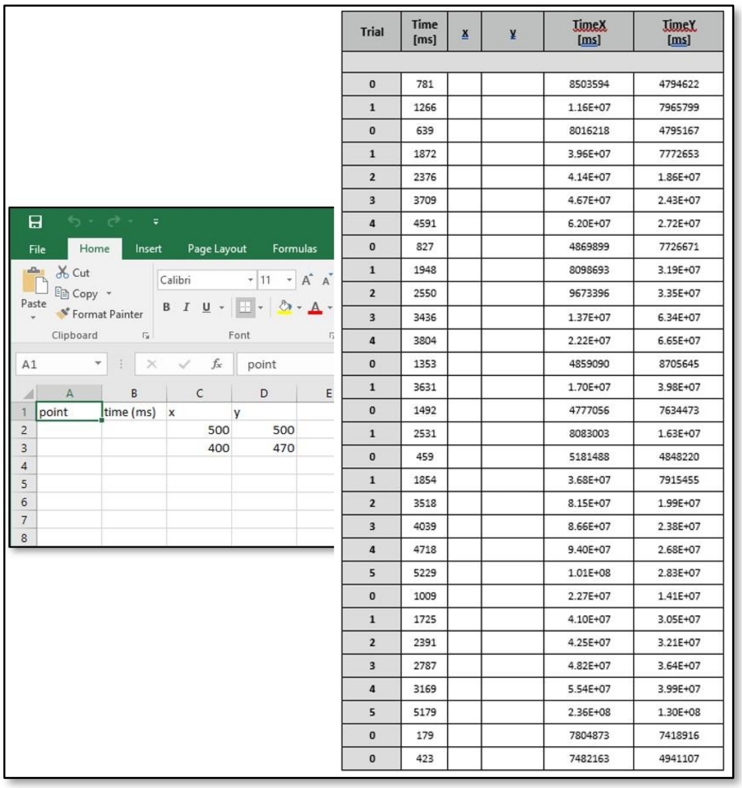


Figure 5 – The mapping occurring between the EMG classification (i.e. the muscle contraction of the subject) and the movement of the mobile cursor on the GUI

- Step 5 - The gird is updated with the projection of the novel cursor position vs the target reference
- Step 6 - If the target is not reached, the process proceeds repeatedly from step 2
- Step 7 - Otherwise the process terminates when the target is reached

4 Preliminary Tests

A set of preliminary tests of the interface has been performed: during these tests, the x_{tg} and y_{tg} target positions were available through an Excel table as mentioned in Section 3.



	A	B	C	D
1	point	time (ms)	x	y
2			500	500
3			400	470

Trial	Time [ms]	x	y	TimeX [ms]	TimeY [ms]
0	781			8503594	4794622
1	1266			1.16E+07	7965799
0	639			8016218	4795167
1	1872			3.96E+07	7772653
2	2376			4.14E+07	1.86E+07
3	3709			4.67E+07	2.43E+07
4	4591			6.20E+07	2.72E+07
0	827			4869899	7726671
1	1948			8098693	3.19E+07
2	2550			9673396	3.35E+07
3	3436			1.37E+07	6.34E+07
4	3804			2.22E+07	6.65E+07
0	1353			4859090	8705645
1	3631			1.70E+07	3.98E+07
0	1492			4777056	7634473
1	2531			8083003	1.63E+07
0	459			5181488	4848220
1	1854			3.68E+07	7915455
2	3518			8.15E+07	1.99E+07
3	4039			8.66E+07	2.38E+07
4	4718			9.40E+07	2.68E+07
5	5229			1.01E+08	2.83E+07
0	1009			2.27E+07	1.41E+07
1	1725			4.10E+07	3.05E+07
2	2391			4.25E+07	3.21E+07
3	2787			4.82E+07	3.64E+07
4	3169			5.54E+07	3.99E+07
5	5179			2.36E+08	1.30E+08
0	179			7804873	7418916
0	423			7482163	4941107

Figure 5 – Results of the preliminary tests as performed with the GUI

Meanwhile the time required to perform the cursor movement was also measured. An example of the data structured reporting the time (in ms) is reported in Figure 5.

These tests aimed at checking the functionality of the system, even if they were only involve the software components. Further tests should validate the feasibility of having human subjects able to improve their capability on moving the cursor into the target as soon as different consequent target are given along the horizontal and vertical axes of the grid.

5 Conclusion

We presented a novel interface based on a new algorithm which implements a set of Cartesian movements on the screen of a computer, namely the grid. Such movements are designed in order to be induced by the muscle contraction of human subjects while trying to reach and match provided target within the grid.

Preliminary tests were performed on the software components of the project: a set of proper tests should be developed were the time required to reach such targets should be measured vs extensive protocols where the subjects improve their performance trial by trial. This set-up should help and support a variety of applications [10, 11], from the control of prosthetic devices to the improvement of the muscular tone of impaired people in a rehabilitative context [12, 13].

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